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ABSTRACT

Smith's 1973 model of articulatory phonological development between the ages of two and four is re-examined in an attempt to develop a model that includes the possibility of both perceptual and articulatory learning. Smith's data, regarding phonological transformations of words after rules established by his infant son's pronunciation of the words "puzzle," "puddle," and "pickle," are re-analyzed in support of two hypotheses associated with a perception model. The re-analysis shows that the child does have, in some cases, a unique, non-adult underlying representation based on a misperception of the adult form. This finding is interpreted as evidence for a model that recognizes two types of phonological rules (perceptual-encoding rules and output rules). Several properties that distinguish the two rule types are identified. (Author,JB)

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THE CHILD'S LEXICAL REPRESENTATION:
THE 'PUZZLE-PUDDLE-PICKLE' EVIDENCE¹

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ABSTRACT. The topic of this paper is the structure of the child's lexical representation. Smith 1973 argues that the child stores the adult surface forms of words and that these forms provide the input to the child's phonological rules. This model formally excludes perceptual learning as a component of acquisition. A re-analysis of Smith's 'puzzle-puddle' data shows that the child does have, in some cases, a unique, non-adult underlying representation--one that is, moreover, based on a misperception of the adult form. This finding is interpreted as evidence for a model that recognizes two types of phonological rules--perceptual-encoding rules and output (or articulatory) rules--and several properties that distinguish the two rule types are identified. The implications of these results for the descriptive adequacy of Smith's model are discussed.

Introduction

Smith 1973 presents a detailed analysis of his son's phonological development between the ages of two and four. The book is impressive, not only for the care with which the analysis was done but also, and more importantly, for the clarity with which central acquisition issues were stated. The analysis of the child's productions was done in two ways: first as a mapping from the adult system and second as a self-contained system. In his introduction, Smith raises seven issues that any theory of language acquisition must address; one of these concerns the nature of phonological change. Smith states that when changes occur in the child's output, they do so in an 'across-the-board' fashion. On the basis of this (and other) evidence, Smith concludes that the child must have the adult surface form as his underlying lexical representation. The implication is clear: the child thus must perceive in an adult-like fashion and the deviance of his/her output is due to the articulatory difficulty of certain sounds and sound sequences (and in some cases to certain formal properties of his mapping system).

FLOID 587

In my own work on Spanish acquisition, I have repeatedly encountered some phenomena which appear to be perceptually-based. Since this work has been done on children somewhat younger and/or less advanced than Smith's child, the discrepancy may partially be a function of the age of the children studied. In addition, however, I have noted that some changes could hardly be described as across-the-board, and that in some of these cases, it seemed most reasonable to infer that the child had the words in question incorrectly stored. As a result of reading Braine's review (1976) of Smith, I became interested in the possibility that Smith's own data might provide evidence for some perceptually based acquisition phenomena; this paper presents the results of that search.

1. I would like to thank David Barton, Will Leben and Neil Smith for helpful comments on an earlier version of this paper, Neil Smith for including all of Amahl's data in his book and thus making possible this re-analysis, and finally Amahl for including pickle among his 'mistakes' since pickle is about as close to *puggle as English ever gets.

The outline of the paper is as follows. I will first review the major aspects of Smith's model (which Braine calls an 'articulatory model') and then present Braine's main criticism of the Smith model and his proposal for a 'perception' model--one which includes the possibility of both perceptual and articulatory learning. Two hypotheses associated with a perception model are presented. The 'puzzle-puddle' data from Smith that I analyzed are described; the results of this re-analysis are discussed with respect to the two hypotheses. The re-analysis shows that the child does have, in some cases, a unique, non-adult underlying representation--one that is, moreover, based on a misperception of the adult form. This finding is interpreted as evidence for a model that recognizes two types of phonological rules--perceptual-encoding rules and output (or articulatory) rules--; several properties that distinguish the two rule types are identified. In the final section, I briefly discuss the implications of these results for Smith's model and some issues concerning the nature of the child's lexical representation that must be left unresolved.

Smith's model

In section 4 of his book, Smith concludes that the data from his son Amahl show that the child's speech is a mapping from the adult system and that there is no useful sense in which the child can be said to have his own self-contained system (i.e. a system characterized by properties distinctly different from those of the adult system). In Smith's view, the child has the adult surface forms of words as his underlying lexical representations for those words. These representations are comprised of all the distinctive features of the adult system and are the input to a set of realization rules that--with a set of phonetic rules--map the lexical representations into the child's surface forms. Since the child perceives in an essentially adult-like manner, the nature of acquisition is primarily a process whereby the child learns to pronounce those sounds which are initially 'unpronounceable'. However, there are also phenomena which are not due to motoric difficulty; these, Smith argues, derive from the formal properties of the realization rules (e.g. the child's hypothesis about the appropriate scope of a particular rule, the 'structural pressure' of the rules, etc.).

To demonstrate the descriptive adequacy of his model, Smith gives evidence for the validity of (1) the adult surface form as the child's underlying representation and (2) the realization rules as the mapping system for the child's output. (As part of his argument, Smith also proposes a set of constraints on possible realization rules, reviews the lack of evidence for the child's own system and offers a possible psychological model for acquisition.) To show that the adult form is part of the child's competence, Smith presents five types of evidence for the position that the input to the child's rules must be the adult form (section 4.1.1) and three types of evidence that show that the realization rules are part of the child's competence rather than of his performance (section 4.1.2). The evidence for the validity of the realization rules is (a) that at least some aspects of development can be characterized as rule simplification and (b) that at least partial rule ordering is required to characterize the output (4.2). I will not discuss the validity of the rules, since, in fact, these arguments presuppose the correctness of the structure of the lexical representations; for example, should the lexical representation of at least some words be shown to not be the adult form, then the form of the rules and possibly

their ordering would also change and by necessity so would any arguments about rule simplification and ordering.

To elucidate the nature of the child's lexical representations, Smith carried out a limited number of tests (occasionally in de-contextualized situations) that showed that Amahl could discriminate minimal pairs which either he did not produce or produced homophonously. In a similar vein, Smith reports anecdotes that show that Amahl could consciously reflect on his inability to say a word correctly or on a new ability to say a word correctly. Although such 'perceptual factors' (section 4.1.1.1) demonstrate convincingly that Amahl certainly knew more about adult words than could be inferred from his output alone, the most convincing evidence for the adult surface form being the child's lexical representation for all words comes from the phenomenon of 'across-the-board' change.² "When a child learns to pronounce a new sound or combination of sounds he immediately utilises it correctly in all relevant words, rather than adding it piecemeal to each word as he re-hears it after his new-found ability (139)"; thus, such "sounds and sound sequences must have been stored in the brain 'correctly' in order for their appearance to be so consistently right (139)". Smith does say that this description is somewhat of an oversimplification, in that "usually any change was spread over a period of several days or, rarely weeks, with free variation between the old and new forms occurring first in a few words, then in a majority, and then again in a few stragglers (140)." His claim though is explicit with regard to the correct application of a change to all and only those relevant words and the fairly rapid process of the change.

To show that the realization rules are part of the child's competence rather than of his performance, Smith presents three areas where the child does not produce a sound or sound sequence which in fact he can produce in other contexts; these are 'puzzles', metathesis and absolute exceptions, and recidivism. Since Smith has already concluded that the child's perception is adult-like (via the arguments for the adult surface form as the child's lexical representation), and since these examples appear to demonstrate that articulatory difficulty per se cannot explain all the child's output, Smith is forced to conclude that in some cases the child is prevented from saying a sound as a result of the "structural pressure of the rules (149)".

Braine's model

In his review of Smith 1973, Braine questions Smith's assumption that the child has the adult form as the lexical representation for all words, although

2. Smith gives three other types of evidence of which only the 'plural formation' one is completely convincing. The argument concerning the use of distinctive features seems circular to me (despite Smith's claim to the contrary), since it is precisely because Smith puts all the adult segments into the child's lexical representations that he then needs the some twenty rules which affect "subtle differentiation on the adult form (p.138)". Finally, the data presented under 'restructuring' simply do not demonstrate that the child has the correct adult segment in his lexical representation (although, they may show that in some stages, the child's lexical representation contains a segment which is different from that in his output).

he readily agrees that the data show that the child knows a great deal more about words than the output would suggest. (Unless otherwise noted, all references to Braine are to Braine 1976.) Braine's most significant criticism stems from his observation that Smith does not systematically distinguish between two kinds of 'free' variation: "one is intra-word variation in the pronunciation of the same word on different occasions," and the "other is inter-word variation in the realization of a segment from one word to another, not attributed to phonological environment (496)". Intra-word variation can be caused as a realization rule becomes optional. However, for inter-word variation to occur, the "differences are presumptively in the lexical entries(496)". Since Smith's model assumes that the child has the correct (i.e. adult) lexical representation, it by definition excludes the possibility of inter-word variation. Braine notes that some of the optional rules do appear to be associated with inter-word variation (i.e. /s/-deletion and velar assimilation). He concludes that such rules could only be of a perceptual-encoding nature in that only optionality in rules which operate 'upstream' of the lexical entries could account for miscoding in the lexical representations. Braine correctly observes that unless it is a statistical artifact "this issue seriously affects the interpretation of 'across-the-board' nature of phonological change (496)".

In Braine's alternative model (see also Braine 1974), three kinds of processes are required to relate adult and child forms: (1) auditory encoding laws, which reflect the relative auditory salience of input segments; (2) correspondence rules, which specify the articulatory analysis made of words in the lexical store at any given point; and (3) output rules which specify feature changes due to phonotactic processes or motor malperformance and which fill in redundant features. Since Braine admits that the correspondence layer is "unfortunately...unlikely to be well-defined", I will simplify Braine's model to a two-level rule system: perceptual encoding rules (i.e. the encoding and correspondence rules), rules that occur upstream of the lexical entry; and output rules that operate downstream of the lexical entry. Thus, the lexical representation represents the codification of the filtering process effected by the perceptual encoding rules and serves as the input to the final set of rules.

In Braine's view, the child's learning task involves both the discovery of the relevant articulatory features that correspond to the auditory features of the input and the discovery of how to pronounce those articulatory features. Braine notes that many of Smith's realization rules fall into the latter category, but that at least three rules (R1 and R2 which involve nasal+obstruent clusters, and R3 the velarization of stops rule that accounts for the 'puzzle' phenomenon) are likely candidates for perceptual-encoding rules. Braine implies that across-the-board change should only be a characteristic of output rule changes, presumably because it is only in these cases that the lexical entry includes the necessary (correct) specification for environment; conversely, perceptual-encoding rule changes should not be across-the-board (i.e. should show inter-word variation). I further hypothesized that if such perceptual-encoding rules do indeed exist and if they operate upstream of the lexical entries, then a further characteristic of perceptual-encoding rule change would be precisely the kind of errors that Smith claims never occurred in Amahl's data--i.e. errors where words that had previously been produced correctly and that also matched the structural description of the perceptual-encoding rule would be incorrectly produced at the time that the perceptual-encoding rule changes.

Hypotheses associated with a perception model

Therefore, the perception model gives the following hypotheses:

Hypothesis 1: 1a. Perceptual-encoding rules will be associated with lexical exceptions (inter-word variation). Hypothesis 1a is based directly on Braine's argument above. 1b. When the associated perceptual 'error' is first detected by the child, the earliest evidence of change will be found in only a few words (i.e. an initial 'piecemeal' stage).

Hypothesis 2. When the perceptual-encoding rule changes, it will be applied incorrectly (from the point of view of the adult system) to some words that also meet its structural description.

Since output rules operate downstream of the lexical entry and thus are in a sense the formal opposite of the perceptual-encoding rules, neither lexical exceptions nor mistakes in rule application should be characteristic of output rule changes (i.e. such output rules have the properties of Smith's realization rules).

Data

For the re-analysis of Smith's data within the context of the above hypotheses, I decided to look at the set of data from Amahl on which R3 (the velarization of stops rule) was based, since Braine suggested that this rule might be a perceptual-encoding rule (see Braine 494, for a brief discussion of the possible acoustic basis of the perceptual error). Further, R3 is a central rule in the 'puzzle' phenomenon which in turn is one of the most interesting cases that Smith presents. Smith himself gets a lot of theoretical mileage out of 'puzzles'. He repeatedly uses it throughout the section in which he argues for the descriptive adequacy of his model. Although Smith does not specifically use 'puzzles' in the section where he argues for the validity of the adult form as the child's lexical representation (4.1.1), he does justify this same claim explicitly for 'puzzles' (i.e. on the basis of a discrimination task) in the 'puzzles' section (4.1.2). In this latter section, he uses 'puzzles' as an example that demonstrates that the realization rules are part of a child's competence, and in 4.2.2 states that the necessity for rule ordering (one of the two types of formal evidence for the validity of the realization rules) is best exemplified by reference to the 'puzzles' (159).

Smith gives the following description of 'puzzles'. "The most interesting instance of the many-many correspondences...is provided by the phenomenon of 'puzzles'. That is, the child appears unable to produce a particular sound or sound sequence in the correct place, but is perfectly capable of producing it as his interpretation of something else. For instance, by completely regular rules puddle was pronounced [pʌgəl] whilst puzzle was pronounced [pʌdəl]. That is, we have the array: /pʌzəl/ → [pʌdəl]; /pʌdəl/ → [pʌgəl] (p.4)".

The rule affecting puddle is R3, the rule that velarizes alveolar stops (/t,d,n/) before syllabic /l/; the conditioning environment may in fact be any [l] after a alveolar stop (p.14). The rule affecting puzzle is R24 which neutralizes the affricates, stridents (e.g. /s/) and the non-sonorant continuants as [d] (or,

in the case of non-initial /f/ as [b]).³ In describing the position of R3 in the ordering sequence, Smith states that R3 must precede R6, R7, R19, R24 (p.24) and R30 (p.101). The motivation for R3 preceding R6 and R19 is that, in Smith's view, R3 is one of the harmony rules; thus, if R3 did not precede R6 (which deletes preconsonantal and final /l/), the conditioning environment for R3 would be lost. Similarly, R3 produces velar segments which in turn provide the conditioning environment for R19 (the velar assimilation rule). The ordering of R3 before R7, R24 and R30 is required for very different reasons. There are four classes of words on which R3 does not operate. The first three classes are: (1) medial st-cluster words (e.g. pistol → [pitəl]); (2) medial alveolar continuant words (e.g. puzzle → [pʌdə]); and (3) a few cases of metathesized words (e.g. difficult → [gipitəl]). Thus, R3 must precede R7 (which deletes preconsonantal /s/), R24 (which produces [{d,t}] for /s/ and other fricatives and affricates) and R30 (which moves a coronal consonant to the right of a non-coronal consonant). In the case of st-cluster words, Smith points out that /st/ is treated as /s/ rather than as /t/ (p.24).⁴ In all three cases, we have phonetic sequences of [X d/təl] which do not undergo velarization. Since R3 is a rule exhibiting the tendency toward consonant harmony (p.165) and this tendency (at an "abstract level") appears to be motivated by "articulatory simplicity and the principle of least effort (176)", Smith is forced to conclude that the exceptional nature of these words is due to the "formal properties of the realization rules". I will return to the teleological nature of this 'explanation' later.

The fourth and final class of words exempt from R3 is a set of words which Smith claims demonstrate the morphological conditioning of a phonological process: e.g. gently → [dɛŋklɪ:] but slightly → [laɪtlɪ:]. Thus, the sequence /tɪ/ is velarized to [kɪ] (by R3) when /t/ and /l/ are part of the same morpheme (e.g. gentle), but is retained as [tɪ] when the /t/ and /l/ are part of different morphemes (e.g. slight + -ly) (p.173). As with the other three types of exceptions, there is a simpler explanation--one possible only in the perception model.

To test hypothesis 1 (a and b), I first constructed a corpus of all / [+coron, -cont] (ə)l/ words (i.e. puddle words, corpus I) and all / [+coron, +cont] (ə)l/ words (i.e. puzzle words, corpus II) that were listed in the diachronic lexicon. These words are given in Table 1 (note that I have included st-cluster words with the puzzle set). In Table 1 (and in the text below), parentheses around an individual word indicate that the word was produced as an elicitation but was not produced spontaneously. For tabulation purposes, I counted a word only once (e.g. sandal); thus, derived forms (e.g. sandals,

3. Following Smith's notation system, vertical bars enclose segments that are presumed to be phonemic in Amahl's system, and the more usual slant lines are used to set off segments that are phonemic in the adult system.

4. There is one word petrol (stages 18 and 21) in which Amahl apparently treated /tr/ as [s] also, although Smith does not discuss this case. Since however R16 (which deletes post-consonantal /l,r,w,j/) had disappeared two stages prior to the first stages in which petrol was produced, there is no need to order R3 before R16. Petrol probably should not appear as an exception to R3 at all (since it was always produced with an [r]). I have included it only because it is similar to the /st/ words in being treated as [s].

Table 1. CORPORA

I. <u>PUDDLE</u> Words	N = 47 ⁽¹⁾
(<u>acquittal</u>)⁽²⁾, <u>antlers</u>, <u>beetle</u>, <u>bottle</u>, <u>bundle</u>, (<u>butler</u>), <u>candle</u>, <u>cattletruck</u>, <u>cock-a-doodle-doo</u>, <u>cuddle</u>, <u>difficult</u>, <u>Donald</u>, (<u>fatlock</u>), <u>fiddle</u>, <u>funnel</u>, <u>gentle</u>, <u>handle</u>, <u>hey-diddle-diddle</u>, <u>hospital</u>, <u>journal</u>, <u>kenne<u>l</u></u>, <u>kettle</u>, <u>ladle</u>, <u>little</u>, <u>mantlepiece</u>, <u>medal</u>, <u>metal</u>, <u>middle</u>, <u>muddle</u>, <u>needle</u>, <u>noddle</u>, <u>paddling pool</u>, <u>pedal</u>, <u>petal</u>, <u>poodle</u>, <u>puddle</u>, <u>rattle</u>, <u>saddle</u>, <u>sandal</u>, <u>spindle</u>, (<u>spittle</u>), <u>throttle</u>, <u>tiddly-pom</u>, <u>tiddly-winks</u>, <u>troddler</u>, <u>tunnel</u>, <u>turtle</u>.	
Special cases:	
1. Derived forms: <u>bottles</u> , <u>blue-bottle</u> , <u>gently</u> , <u>pedalling</u> , <u>sandals</u> , <u>sandalwood</u> .	
2. Morphological conditioning cases: <u>badly</u> , <u>completely</u> , <u>friendly</u> , <u>hardly</u> , <u>quietly</u> , <u>slightly</u> , <u>softly</u> , <u>tightly</u> .	
3. Questionable: <u>itself</u> .	
II. <u>PUZZLE</u> Words	N = 21 ⁽¹⁾
<u>chisel</u>, (<u>cudgel</u>), <u>icicle</u>, <u>muscle</u>, <u>muzzle</u>, <u>Nigel</u>, <u>nozzle</u>, <u>parcel</u>, <u>parsley</u>, <u>pencil</u>, <u>petrol</u>, <u>pistol</u>, <u>postal</u>, <u>puzzle</u>, <u>Russel</u>, (<u>satchel</u>), <u>tassle</u>, <u>testicle</u>, <u>thistle</u>, <u>weasel</u>, <u>whistle</u>.	
Special cases:	
1. Derived forms: <u>parcels</u> , <u>pencils</u> , <u>whistling</u> .	
2. Morphological conditioning cases: <u>nicely</u> , <u>smoothly</u> .	
III. <u>PICKLE</u> Words	N = 8 ⁽¹⁾
<u>buckle</u>, <u>circle</u>, <u>pickle</u>, <u>tickle</u>, <u>triangle</u>, <u>uncle</u>, <u>winkle</u>, <u>wriggling</u>. (n.b. <u>wriggle</u> does not appear in lexicon).	
Special cases:	
1. Derived forms: <u>tickling</u> , <u>circles</u> .	
2. Morphological conditioning cases: <u>quickly</u> .	

(1) N does not include 'special cases'.

(2) () indicates an elicited form which was not produced spontaneously.

sandalwood) are listed under 'special cases' and are not included in the total for each corpus from which percentages are calculated. Under puzzle words, I have included two metathesized forms (icicle → [aɪkɪtəl] and testicle → [tɛkɪtəl]). These could be considered exceptions to R3; however, Smith notes that in these words the [t(ə)ɪ] sequence comes from an underlying /s/ or /st/ sequence (where /st/ is [s] in Amahl's system) and thus are not true exceptions. Under puddle words, I have included two metathesized forms also: difficult → [ɡɪpɪtəl] and itself → [ɪtɪlɪf]. On page 100, Smith states that self → [ɪlɪf] is a metathesized form (where /s/ → 0, R7). Smith would not consider these to be exceptions because R3 is ordered before R7 and R30. Since the ordering of R3 before R30 is used solely to handle difficult (as Smith admits, p.101), I have listed this word under the exceptions to R3. Since Smith orders R3 before R7 on other grounds (i.e. st-cluster words like pistol), I will put itself in the special cases category, although I feel that a good argument can be made for this word as a true exception to R3. Note, however, that the ordering of R3 and R7 is also established to handle the exceptions to R3. Dandelion was also difficult to categorize. Since the conditioning environment for R3 could be any /l/ after a coronal stop, dandelion which was produced with the correct [d] could be considered an exception to R3. To do so would be stretching the definition of the conditioning environment, and so I have listed it under special cases also.

After compiling the corpus, I next determined which words were lexical exceptions to either R3 (puddle words) or to R24 (puzzle words). Smith states that R3 becomes optional at stage 29 and that R24 changes at stage 20. To be an 'exception' then, a puddle word would have to be correctly pronounced as [X təl] prior to stage 29 or as [X səl] after stage 20; in the latter case, we would assume that the surface form is equivalent to the underlying form in which case R24 could incorrectly operate on an underlying /{t,d}/. To be an exception, a puzzle word would have to be produced as [X ɡəl] (in which case, R3 would have incorrectly operated on an underlying /{s,z}/, a possibility disallowed in Smith's system by rule ordering), or as [X {ts,s}əl] prior to stage 20. The results are given in Table 2.

To test hypothesis 2, I constructed a corpus (III) of all [-ant,-coron,-cont] (ə)ɪ/ words (i.e. pickle words). These are also given in Table 1. The procedure for identifying 'special cases' was the same as that for puddle and puzzle words. Evidence which would support Hypothesis 2 would be words which would be produced incorrectly as [X təl] during stage 29 (i.e. when R3 changes (/X təl/ →) [X kəl] → [X təl]). These results are given in Table 2 also.

Results

Table 2 shows that of the 48 puddle words, fully 21.3% are lexical exceptions, in the sense that either these words never were subject to R3 (e.g. little, tiddly-pom, Donald, (fetlock), funnel, tunnel and difficult) or they were words which changed to the correct adult form considerably prior to stage 29 (e.g. beetle, medal and possibly cuddle) (IA, Table 2). To see that these are in fact exceptions, note the following pairs and their conditioning environments: (1) /tɪl/ bottle → [bɒkəl] (stage 14), beetle → [bi:təl] (stage 11); (2) /nəl/ journal → [dsə:ɪl] (stage 28), tunnel → [tʌnəl] (stage 28); (3) /dɪl/ tiddly-winks → [tɪɡəlɪ:wɪŋks] (stage 23), tiddly-pom → [dɪdəlɪ:pɒm] (stage 11). These

I. PUDDLE Words N = 47A. EXCEPTIONS -- i.e., where R3 does not operate on a PUDDLE word, prior to stage 29.

- | | |
|-----------------------|---|
| (1) <u>beetle</u> | bi:gu (1), bi:təl (11) |
| (2) <u>cuddle</u> | kədəl (18), but kəgəl (25) |
| (3) <u>difficult</u> | gɪptu/gɪptul (13), gɪpətul (16), gɪfətəlt (20),
gɪfətəlt/gɪpətəlt (22), dɪfkəlt (26),
dɪfɪkəlt (27) |
| (4) <u>Donald</u> | dənəld (27) |
| (5) <u>(fet)lock</u> | (wɪtlək/wɪtlək) (12) |
| (6) <u>funnel</u> | fənəl (28) |
| (7) <u>little</u> | ɫɪdɪ: (1), ɫɪdɪ:/lɪdɪ: (4), lɪdɪ: (9), lɪdɪ:/
lɪtəl (11), lɪdɪ:/lɪtɪ: (13), lɪtəl (14),
lɪtəl/lɪəl (29) |
| (8) <u>medal</u> | mɛgəl/mɛdəl (14) |
| (9) <u>tiddly pom</u> | dɪdɛli:pəm (11) (n.b. <u>tiddly winks</u> tɪgɛli:wɪŋks (23)) |
| (10) <u>tunnel</u> | tənəl (28) |

$\frac{10}{47}$	=	21.3%
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B. ERRORS -- i.e., where a presumable R3 domain word undergoes R24 change at stage 20 (e.g. little [lɪtəl] → *[lɪsəl]).

NONE

II. PUZZLE Words N = 21A. EXCEPTIONS -- i.e., where R24 does not operate on a PUZZLE word, prior to stage 20.

NONE

B. ERRORS -- i.e., where a presumable R24 domain word undergoes R3 prior to stage 29 (e.g. puzzle -- *[pəgəl]).

NONE

III. PICKLE Words N = 8A. ERRORS -- i.e., where PICKLE words are changed to [t,d]əl when R3 becomes optional at stage 29.

- | | |
|----------------------|---|
| (1) <u>circle</u> | gə:gu (8), gə:kul (10), tə:kəl (14) sə:kəl (23)
sə:təl (29) (n.b. <u>circles</u> sə:kəlz (21), sə:təlz (29)) |
| (2) <u>pickle(s)</u> | pɪkəl (23), pɪkləz (25), pɪtəl (29) |
| (3) <u>winkle</u> | wɪntəl (29) |

$\frac{3}{8}$	=	37.5%
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words are true counter-examples to the across-the-board nature of change. Since such inter-word variation is assumed to be evidence for the operation of a rule upstream of the lexical representation, Hypothesis 1a is supported. To the extent that beetle, medal and cuddle demonstrate a piece-meal stage in phonological change, Hypothesis 1b is supported.

In contrast, there are no lexical exceptions to R24 (IIA, Table 2). This means that no [+cont] consonants were produced as velar stops and also that when R24 became optional and/or dropped out only those words which had an adult segment /s,z,tʃ, dʒ,(tr)/ were produced as [{ts, s}]. Since the surface form of the puzzle words prior to stage 20 contained the phone [{t,d}], and this phone also appeared in the surface form of the puddle words little, tiddly-pom, (fetlock) and difficult, we might expect the pronunciation of these words to change also (IB, Table 2). That they did not is further evidence that the puzzle and puddle words were stored differently; more precisely, that the puzzle words correctly contained an underlying fricative or affricate segment and that these four puddle words contained an underlying alveolar stop segment. In agreement with Smith, I also found no puzzle words produced with [{g,k}] (IIB, Table 2). I conclude that the lexical representations for puzzle words were similar to the adult surface forms for these words, in that the child's lexical representations contained at least the feature specification [+cont]. (I could not, however, find convincing evidence that fricatives were distinguished from affricates; here, the child's lexical representation may not have been identical to the adult surface form.) Finally, the 'across-the-board' nature of R24 change demonstrates that R24 does operate downstream of the adult-like lexical representations.

The data from Table 2 I and II presented so far are consistent with the hypothesis that R3 and R24 are quite different: R3 does appear to be a perceptual-encoding rule, while R24 is an output rule. Further evidence comes from the following additional findings. First, R3 operates nearly a year longer than R24 (i.e. there is nearly a year between stage 20 and stage 29). It seems reasonable to expect perceptual-encoding rules to be more difficult to change and that therefore the evidence for such a rule (i.e. incorrectly stored lexical representations) will persist longer. Secondly, Amahl used 16 puddle (i.e. 34.0% of the total) during stages 1 through 10 and only 2 puzzle words (i.e. 9.5%). This asymmetry may be due to an avoidance strategy wherein words containing an articulatorily difficult sound ([+cont]) are avoided; a perceptually-based avoidance strategy is, on the other hand, not likely.

However, the most convincing evidence for R3 as an upstream rule is found in Table 2 III. At stage 29 when R3 becomes optional and some puddle words are changed from [X {g,k}əl] to [X {d,t}əl], three words phonemically /kəl/ also change to [təl]: circle, pickle and winkle. This is particularly surprising because circle had been produced correctly with a [k] since stage 8 (cf. the entries for stages 8, 10, 14, and 23) and pickle from stage 23 (cf. the entries for stages 23 and 25). Winkle was new to Amahl's lexicon at stage 29, and thus we have no evidence for any lexical representation other than [X təl]. Note that none of Smith's rules account for the forms found in circle, pickle and winkle at stage 29 and that Smith does not at any place comment on them.

To determine whether or not random substitutions of [t] for /k/ or /g/ were characteristic of Amahl's speech at stage 29, I checked all those words

containing a /k/ or /g/ (in any position). I looked at the most recent entry for each word and assumed that that entry represented that word's pronunciation at stage 29. I found sixteen other, individual words (i.e. not counting duplicate, derived forms) where Amahl produced a surface segment different from the expected velar stop. Nine cases were words subject to either R8 (i.e. where /k/ → [p]/CwV_/) or to the unstressed syllable strategy (cf. the discussion of ri- and in- on p. 172). In two words, the velar stop was deleted from a cluster, and in one word it assimilated to a labial (this however is in a very early word, grampa at stage 2). In four words, however, the velar stop was produced as an alveolar stop: abracadabra (stage 28), connector (stage 18), cracked (stage 13 once with an initial [t] and twice with an initial [k]; n.b. crack is recorded at stage 19 with the correct initial [k]), and gag (stage 13; n.b. gag was an elicited word only and was produced with either an initial [d] or an initial [g]). Thus, out of literally hundreds of velar stop words, Amahl only produced seven errors of the form /g,k/ → [d,t]. That three of these productions were in /X {g,k}əl/ words, that moreover these three words represented 37.5% of the total set of /X {g,k}əl/ words, and that these errors occurred during stage 29 is not likely due to chance.⁵

The mistakes that appear in these three words provide strong support for Hypothesis 2. In addition, they demonstrate that the non-exception puddle words were also stored, incorrectly, with a velar stop and that R3 is a perceptual-encoding rule operating upstream of the lexical entry. Smith himself recognized that the occurrence of such mistakes would be a "clear indication" that the child's internalized form is not the adult one (139-140). Thus, the data from this puzzle-puddle-pickle analysis show clearly that some aspects of a child's 'malperformance' are due to perceptual errors, while others are due to articulatory problems. This supports Braine's model since it demonstrates that at least part of the child's development involves perceptual learning.

I am claiming then that the non-exception puddle words are stored with a velar stop and that in fact "/t/ and /d/ [and also /n/] are perhaps 'misheard' as the velars /k/ and /g/ in the environment of a following velarized /l/ (p.150)". Smith explicitly says that this is not the case, because Amahl "can easily identify such pairs a riddle and wriggle correctly (p.150)". I would first like to point out that riddle and wriggle were not words in Amahl's active vocabulary in that neither appears in the lexicon (n.b. wriggling does, however). Moreover, none of the pickle words in his lexicon forms a minimal pair with any of his puddle words. Clearly then, for all puddle and pickle words that he 'knew' (i.e. as inferred solely from his production), other phonetic cues (in addition to contextual cues) could serve to distinguish pairs which would be homophonous on the basis of an underlying [k,g] alone.

Let us assume though that Amahl could identify riddle and wriggle and that in addition he could do so in a de-contextualized situation. I am, however, also arguing that R3 is an upstream rule partially because it does have lexical

5. Braine (pers. commun.) pointed out that the [t] for /k/ productions of cracked and gag occurred at stage 13 when the velar assimilation rule was disappearing and when [dɔg] was replacing [gɔg] for dog; thus, these words may be mistakes analogous to the mistakes (of circle, pickle and winkle) that occurred at stage 29 when R3 was disappearing (cf. also fn.6).

exceptions. To explain Amahl's correct identification of these words, I would have to conclude that riddle was just such an exception. Without evidence from his production, this conclusion must remain speculative. The point is, however, that it is dangerous to generalize from the evidence of discrimination in a few cases to the conclusion that the child can discriminate all instances of a contrast (as Smith repeatedly does) and that it is even less defensible to do when we realize that the contrasting pair is selected from particular rule-governed classes, one of which characteristically contains many lexical exceptions in the first place. It of course is obvious that it is not possible to generalize from evidence that in some cases a child stores words incorrectly to the conclusion that in no cases does the child have the correct adult form as his lexical representation. I agree with Braine that there is more to the problem than two mutually exclusive positions would predict.

Implications

There are two levels at which the reanalysis of R3 as a perceptual-encoding rule affects Smith's model: first at the specific level of Smith's description of the 'puzzle/puddle' data; and second at the level of Smith's arguments for the descriptive adequacy of his model.

First, since it is an upstream rule, R3 simply drops out of the ordering sequence for the realization rules.⁶ Since R3 is not a harmony rule, there is no reason to expect harmony changes in the surface forms of the 'exception' words: pistol, puzzle, difficult, and slightly. Thus, it is not the case that Amahl was prevented from saying puddle correctly because of the 'formal properties of the realization rules'; that is, Amahl did not produce puddle and puzzle differently because he had hypothesized that the scope of the velarization rule only covered stops (p.150), but because he heard them differently.

Two other points can be made about the puzzle/puddle data. First, we might expect Amahl to produce slightly as [X kli], if in fact R3 is directly related to how Amahl 'hears' coronal stops (n.b. glottalized coronals) before a (dark) [ɪ]. Smith says that R3 is blocked in these words by the morpheme boundary. Unless of course it is in the adult speech that the morpheme boundary blocks a production rule (i.e. so that the input then lacks the acoustic cues that Amahl 'mishears' as [k,g]), it seems more reasonable to restate this 'condition' in the following way: it is precisely in those cases where Amahl has the alternate monomorphemic form (e.g. quiet) that he can (re-)construct the 'correct' underlying form for the derived variant (quietly); alternatively, it is because he already has the correct underlying representation (quiet) that he can 'hear' the derived variant correctly. For six of the eight -ly words in the puddle set, Amahl used the monomorphemic form from four to twenty stages prior to the derived form. (The two exceptions are slightly and completely.)

6. It would be interesting to determine the extent to which the necessity for rule-ordering is correlated with aspects of the analysis based on the theoretical approach, in this case on the inclusion of all adult phonemes--with the complete adult distinctive feature matrix--in the child's lexical representation. Certainly the recognition of a velar stop in the lexical representations for the non-exception puddle words affected both the rule ordering and the set of distinctive features needed in the rules.

I would also suggest that the child's perception is the crucial factor in the behavior of the st-cluster words: (exceptions listed under (a) above). Smith states that whereas /s/ is deleted in /sp/ and /sk/ clusters, /st/ clusters are treated like [s] (cf. p.60). Apparently in the homorganic clusters, the cue for the stop is not perceived or not recognized as distinctive. Smith further notes that in several cases, "we appear to have a reinterpretation by the child of a sequence of segments as a unit (p.167)". Although 'reinterpret' implies that the child hears or stores both segments, I would suggest that such cases are also due to perceptual-encoding problems (i.e. the child 'interprets...'). Similarly, the marked voiceless frication in /t+r/ is probably a central factor behind the treatment of /tr/ as [s].

In conclusion, I will briefly comment on the implication of the re-analysis for arguments Smith presents for the descriptive adequacy of his model. This will be brief because the results presented here only directly affect Smith's arguments concerning the validity of the adult surface form as the child's lexical representation and secondarily Smith's claim that the realization rules are part of the child's competence. As noted before, however, his arguments for the validity of the realization rules must, by necessity, be affected once the lexical representations (for some classes of words) are re-formulated.

With regard to the first issue, I believe that the exceptions to R3 and the number of mistakes of its application (i.e. to circle, pickle and winkie) demonstrate clearly that not all changes are across-the-board (i.e. always consistent and correct); on this basis and also because we have a plausible explanation for the acoustic motivation for R3 (cf. Braine 1976, 493), we may conclude that the non-exception puddle words were in fact incorrectly stored (e.g. words like puddle, muddle, etc.). Thus, Smith cannot claim that the adult surface form is the child's lexical representation in all cases. I would further suggest that the instances of what Smith calls 'restructuring' are also cases in which the child has mistakenly represented the lexical shape of particular words. Once we admit non-adult-like lexical representations for some words, it should also be the case that not all the features which characterize the phonology of the adult system would be necessary to characterize the child's system. To summarize, the results of this re-analysis substantially weaken the major argument (i.e. the across-the-board nature of change) that Smith puts forth for the validity of the adult form as the child's lexical representation. Braine points out that the second type of evidence ('restructuring') actually "say[s] nothing about the form of the representation (p.492)" and would be just as explicable (I would say 'more convincingly explained') by a perception model. The third type of evidence ('the need for all distinctive features') is in my opinion inherently weak since it is partially definitional.

In contrast, the final two arguments ('perceptual factors' and 'plural formation') do demonstrate that in some/many cases the child does have words stored in an essentially adult-like form. Also, the clearly across-the-board nature of R24 change demonstrates that the puzzle words were correctly stored as [+cont]. We have then simply a modification of Smith's claim about the child's lexical representation.

The final 'descriptive adequacy' issue that I will discuss concerns Smith's claim that the realization rules are part of the child's competence. This

claim is based on evidence--as interpreted by Smith--that shows that the properties of the realization rules themselves account for some aspects of the child's output. The argument is as follows: if there is a class of data which can be attributed neither to motoric difficulty nor perceptual problems, then these data can only be accounted for by reference to the structural pressure of the realization rules. As must be obvious by now, I will object to this claim on the grounds that Smith has not--and can not--rule out perceptual problems.

The evidence is then from "three areas where it appears that, despite his undoubted ability to produce sounds or sound sequences identical to those of the adult language, the child in fact does not (p.149)". The three areas are (1) puzzles, (2) metathesis and absolute exceptions, and (3) recidivism. Recidivism is not actually evidence, because in neither example that Smith gives does Amahl actually produce a sound "identical" to its source sound in the adult language and then at a later stage lose the correct pronunciation; the two examples are cases in which Amahl produces a sound substitution in stage *n* which are judged to be more like (but certainly not identical to) the correct adult phoneme than that sound substitution that Amahl produces for the same adult phoneme at stage *n*+1. Braine argues that the cases of 'recidivism' can be viewed as examples of incomplete perception (p.493).

If R3 is a perceptual-encoding rule as I have argued, there is no need to refer to a 'formal property of the realisation rules' (i.e. Amahl's hypothesis about the scope of R3; to explain why puzzle was [pʌgəl] but puzzle was [pʌdəl]. 'puzzle' is in fact no longer a puzzle. Similarly, since R3 is not a harmony rule, it is not surprising that in the cases of 'metathesis' (e.g. icicle, testicle and difficult), a coronal stop is produced correctly.

I have already discussed Braine's claim that 'absolute exceptions' cannot be explained in Smith's model, since realization rule optionality can only account for intra-word variation. Smith in the section on 'absolute exceptions' gives three examples: distance → [dɪtən] (where the predicted form would be [dɪtət]); very → [vɛɪ:] (where the predicted form would be [vɛɪ]); and little → [dɪdɪ:] or [lɪdɪ:] (where the predicted form would be [d/lɪgəl]). little is of course only one of eleven exceptions to R3; without examining the corpora from which distance and very come, I cannot say for sure that the rules involved regularly show exceptions of the type characteristic of perceptual-encoding rules. However, Smith's 'explanation' is vague and not very convincing either: "Again, hypothesizing the psychological validity of the realisation rules, and the corresponding structural pressure these exert, will give a satisfactory explanation for these apparently anomalous discrepancies (p.152)".

Braine comments explicitly on the unusual nature of an explanation of this sort. It implies "something extraordinary going on in A's head: that he knows how to make a particular feature, but (for reasons having nothing to do with its motoric difficulty) refrains from making it and makes another instead--and then, some weeks later, changes his mind and decides to realize it after all! In short, the only way I see to make sense of the articulation hypothesis [i.e. model, here] is to reconstrue it as the perception hypothesis [i.e. model] (494)". For the most part, I agree. The puzzle/pickle data presented here provide considerable support for Braine's hypothesis that some words are incorrectly stored, just as the puzzle data support Smith's argument for the validity of the

operation of some realization (or output) rules on adult-like lexical representations.

In conclusion, I would like to emphasize that the results of the reanalysis presented here leave unresolved several issues regarding the child's lexical representation. The point of the paper has been to demonstrate that it is not the case that the child has the (correct) adult surface form for all words as his or her lexical representation of those words. The reanalysis has shown that there are two separate types of rules with distinctly different properties. The first type is characterized by several/many lexical exceptions and a process of change that is slow and results in 'errors' (R3). The second type does not have lexical exceptions; when rules of this type change, they do so in an across-the-board fashion--i.e. rapidly and correctly to all relevant words (R24). I have argued that rules of the first type operate upstream of the lexical representation; I have called these rules 'perceptual-encoding rules'. Rules of the second type are in this view 'output rules'--rules which operate downstream of the lexical entry. On the basis of the puddle-pickle data, it is quite clear that in fact some words may be incorrectly stored and that therefore a part of the child's acquisition process must include perceptual learning. It remains to be seen, however, to what extent perception versus production 'incompetence' rules account for the structure of the child's lexicon.

An equally important question that remains is: are there other factors--distinct from perception incompetencies--which account for non-adult components in the child's lexical representation. Smith raises the issue that formal properties of the realization rules account for some discrepancies; Braine asserts that perceptual malperformance rules provide a more satisfactory explanation. The results presented here demonstrate that perceptual malperformance does provide a plausible explanation at least in the particular cases in which Smith is forced to make reference to formal properties of the rules. Braine however also remarks that this 'explanation' is, from a psychological standpoint, unusual; on this point, I cannot fully agree with Braine. There is evidence in the literature that suggests that children (particularly children younger than Amahl) do produce fairly adult-like renditions of some words prior to a stage in which 'systematization' takes place: after a particular rule is learned or invented by the child, his or her productions of some words do 'lose' their former accuracy. Whatever the gains of such systematization for the child, the changes thus affected in the child's lexical representations cannot be attributed to perception or production malperformance per se. A possible example of this phenomenon from Amahl's data is R29 which generalizes linking /r/ to non-linking position. Smith gives this rule as one of two rules which exemplify a minor function of the realization rules: to minimize the number of morpheme structure conditions (a function that, by the way, does not fit in well with Smith's model of lexical representation plus realization rules). The other rule that exemplifies this function of realization rules is R27 which inserts homorganic consonants after nasal consonants; Smith states that R27 is a generalization of Amahl's new-found ability to produce nasal+consonant clusters. In the view presented here, Amahl's nasal+consonant cluster deletion rules would be perceptual-encoding rules and the 'errors' of R27 are completely analogous to the pickle errors. It may be that R29 is also a similar case.

Thus, although we have found an 'explanation' more acceptable to Braine

for the 'puzzle-puddle-pickle' phenomenon, the results presented here do not rule out the importance of other factors related to the child's active systematization or organization of phonology, one factor of which may be like Smith's 'formal properties of the realization rules'. This issue remains open.

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